

SPACE PROBE RADAR ALTIMETER STUDY

Volume II  
DEVELOPMENT PLAN

November 1966

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Prepared under Contract No. NAS 1-5953

by

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Aerospace Division  
Baltimore, Maryland

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Langley Research Center  
Hampton, Virginia



## FOREWORD

Westinghouse Electric Corporation, Aerospace Division, Baltimore, Maryland, has investigated the system requirements of a radar altimeter applicable to deep space probes. The study has been conducted under contract NAS 1-5953 with the National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia. The Westinghouse order number was AAD-53449.

The results of the study are presented in three volumes. Volumes I and III are the technical report and reliability plan, respectively. This document, Volume II, describes a plan for the altimeter's design, development and production.



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## INTRODUCTION

Westinghouse Electric Corporation, Aerospace Division, has conducted a Space Probe Radar Altimeter (SPRA) Study under Contract NAS 1-5953 for NASA's Langley Research Center. Under this program was developed the conceptual design of a small, low power consuming, sterilizable altimeter. In addition, a plan was evolved for the design, development, and production of altimeters for a space probe mission. The development plan, complete with cost information, is presented herein.

This document plus the "Technical Report" (Volume I), the "Reliability and Quality Assurance Plan" (Volume III), and the "Space Probe Radar Altimeter Engineering Drawings," comprise the contract final report.

The following Development Plan describes the program organization and schedule required to develop the radar altimeter, and it details the management, engineering, manufacturing and test plans.



## PROGRAM DESCRIPTION

This development plan describes a program for the design, development, and production of altimeters required for a deep space probe mission. The object of the program is to commit to practice the concepts developed during the study effort of the SPRA program.

### Goals

The developed altimeter will provide altitude information for correlation of scientific measurements, parachute deployment, and other functions requiring altitude marks. Altimeter design has been predicated on the requirements of probes such as a Mars "semi-hard" lander launched in 1971.

While the altimeter design is suitable for a variety of possible applications, the development plan has been formulated to be compatible with a hypothetical 1971 Mars probe. This has established overall timing, critical dates, and the level of development allowed. The assumed program go-ahead date is January 1, 1967. Development programs for components and subassemblies have been limited to approximately one year, and consist of no more than adapting existing techniques. Unproven ideas have been excluded to assure high confidence in success and to avoid potentially unreliable techniques.

Reliability and quality control requirements have very significant impact on the conduct and cost of the altimeter development program. Quality assurance provisions in accordance with NPC-200-2 have been assumed. Volume III of this report is devoted specifically to these areas, and describes the SPRA reliability and quality assurance plans.

Plans have been made for the fabrication of fifteen altimeters: one engineering model; two prototypes; two units for environmental qualification testing; and ten final configuration units for system-level tests and evaluation, operational use, and spares. Documentation of program results will also be provided as described later.

### Organization

General organization of the program is as shown in Figure 1. The Program Manager's responsibilities include direction, coordination and control of all program activities of the management organization, and of all line personnel assigned to him from line departments as needed to carry out program requirements.

The Technical Director, with the assistance of an advisory staff, has responsibility for direction and coordination of the activities of design and support personnel. Approval of technical decisions, subassembly interface control, and technical liaison with NASA and other contractors will be among his duties. Responsibility for various areas of effort (i.e., electrical and mechanical design, reliability, manufacturing, etc.) will be placed in the hands of personnel assigned to the project from the various line departments.

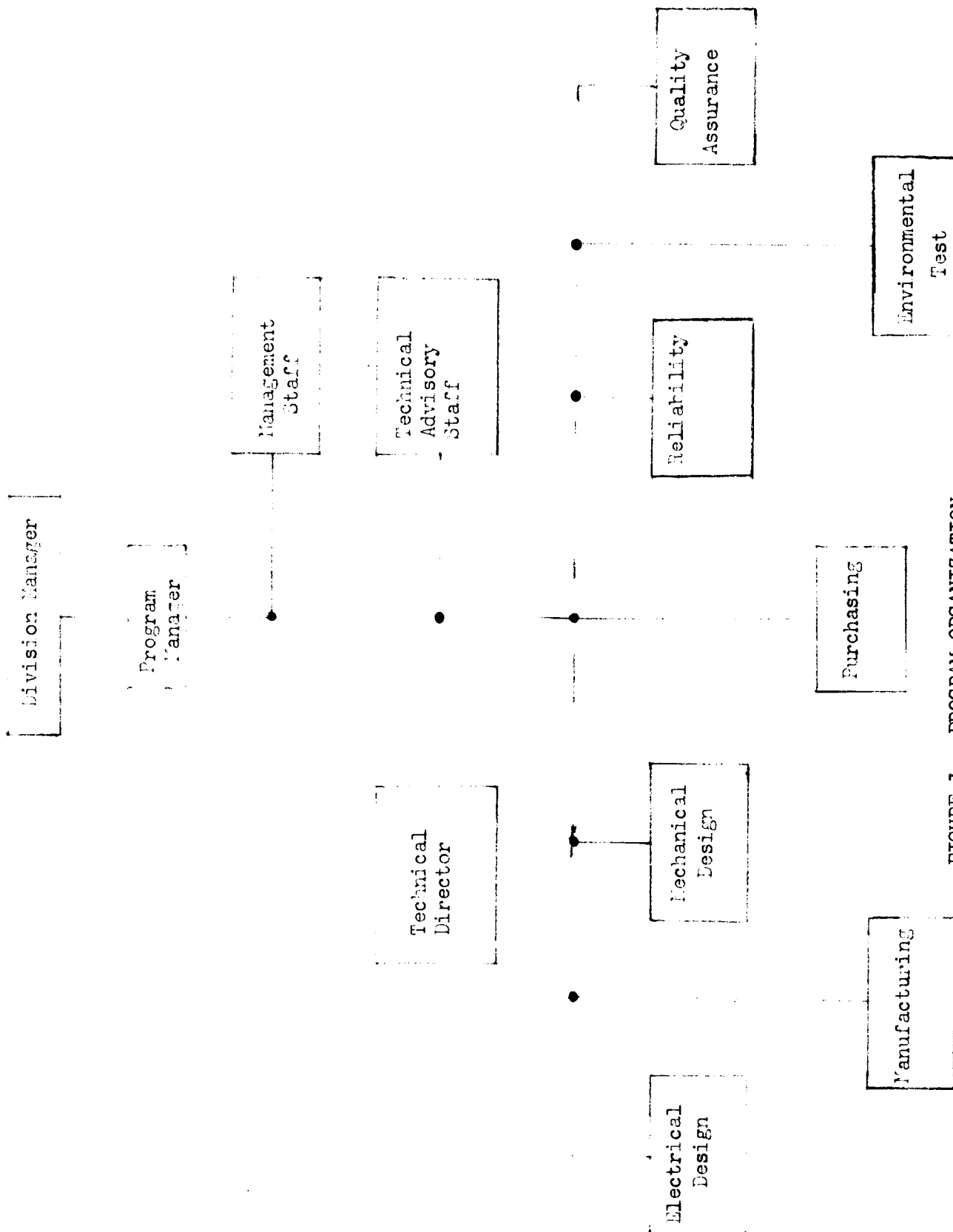


FIGURE 1. PROGRAM ORGANIZATION



## SCHEDULE AND PLANNING NETWORK

## Schedule

In accordance with the requirements of the contract work statement, the development plan is based on the assumption of a 1971 space probe. Figure 2, the master schedule for development and production, reflects the timing necessary for a 1971 Mars mission. Four altimeters would be completed for the 1971 Mars launch window - - two for operational use and two for spares. Six units would be delivered for systems-level testing, including an earth entry mission a year prior to the operational mission. The three-phase program is as described below:

Design and Development. - Under this phase a breadboard engineering model altimeter will be designed, fabricated, and bench- and temperature-tested. Prototype design, incorporating changes dictated by the breadboard test program, will follow. The prototype electrical and mechanical configuration will conform to final unit requirements. One prototype will undergo bench and temperature tests in conjunction with test equipment designed to simulate realistic dynamic inputs. A second will be delivered for initial capsule integration and interface checkout.

Manufacturing Phase. - The manufacturing phase includes tooling and manufacturing development, modification of existing clean room facilities to conform to the dictates of the altimeter sterilization goals, fabrication and assembly, and the exercise of a comprehensive quality control program. A total of 12 final units will be produced - - 2 altimeters for environmental and qualification testing and 10 for delivery to the customer.

Test Phase. - Comprehensive environmental and qualification tests will be performed. All critical environments will be simulated. Additionally, component testing will be conducted during the early phases of development as a part of a reliability program which is a continuous effort throughout.

## Work Responsibility

Responsibility for the various tasks of the SPRA program will be divided into the following major areas under the direction of the Program Manager: management, engineering, reliability, manufacturing, quality assurance, environmental test, and purchasing. The general breakdown of duties under each of these functional areas is as listed below.

Management. -

- Planning and scheduling
- Progress monitoring and control
- Cost control
- Configuration control
- Customer liaison
- Documentation

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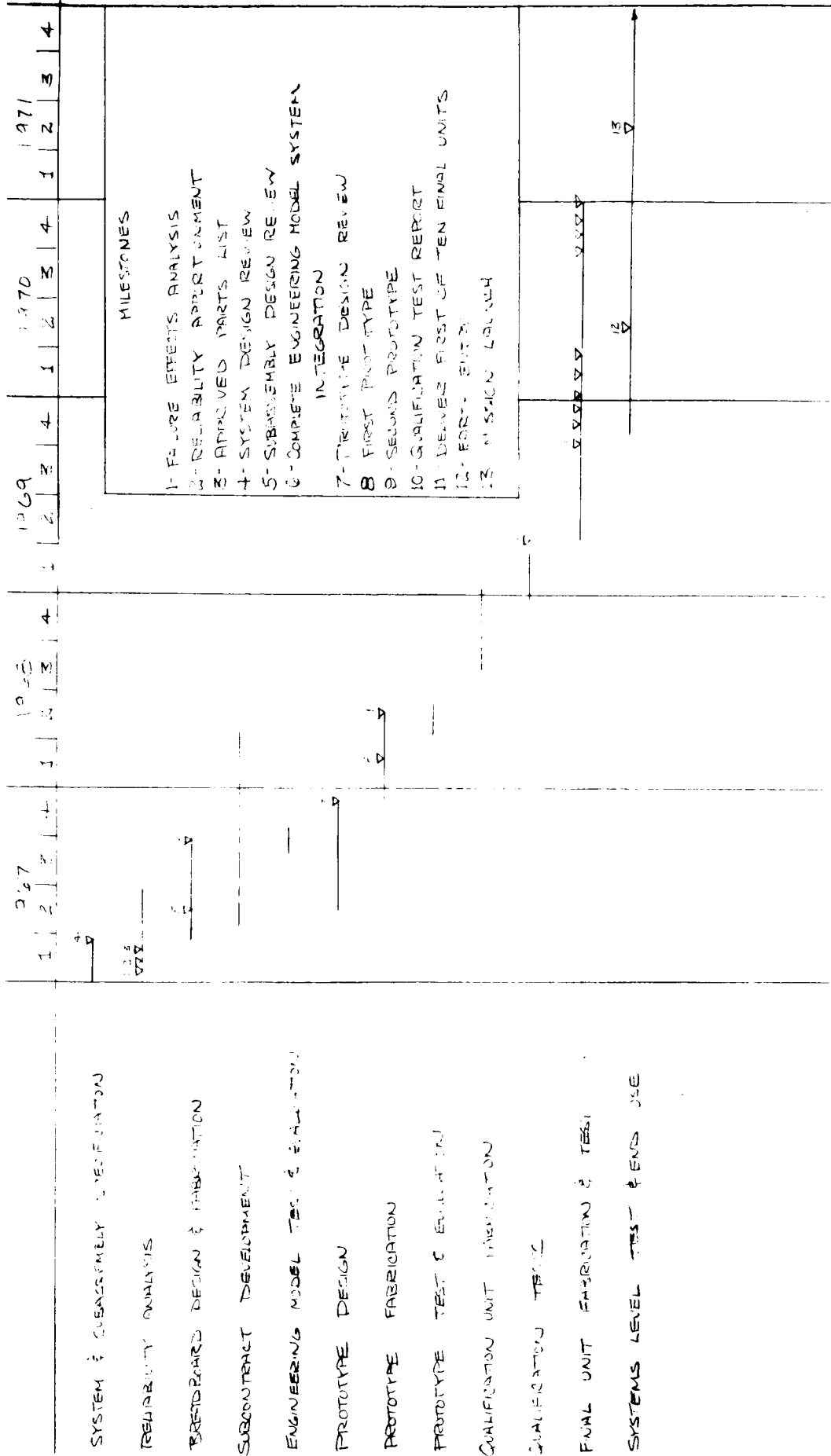


FIGURE 2. - DEVELOPMENT AND PRODUCTION SCHEDULE

Engineering. -

- Analysis
- Design and development
- Technical liaison
- Vehicle interface
- Breadboard fabrication
- Test and evaluation
- Drawings and specifications
- Consultation with manufacturing and product reliability
- Operations support

Reliability. -

- Parts selection
- Parts application
- Parts evaluation
- Parts specification
- Parts vendor liaison
- Reliability prediction
- Trade-off analysis
- Reliability apportionment
- Failure analysis
- Design review
- Subcontract reliability requirements and control
- Reliability monitoring
- Design consultation and support

Manufacturing. -

- Preproduction control - design reviews
- Facilities and tooling for fabrication and assembly
- Coordination with purchasing, engineering and product reliability
- Personnel training
- Manufacturing development
- Materials management
- Second sourcing and subcontracting recommendations
- Fabrication and assembly
- Shipping

Environmental Test. -

- Facilities and fixtures for environmental test
- Test planning and specification
- Environmental tests
- Test reporting

Quality Assurance. -

- Monitoring of supplier quality assurance procedures
- Incoming parts, test and inspection
- Feeder test and inspection
- System acceptance test
- Process controls
- Field quality control
- Equipment support - calibration and repair

Purchasing. -

- Proposal solicitation and evaluation
- Negotiation
- Subcontract control
- Source selection
- Parts procurement
- Cost reporting

## Planning Network

The flow chart of Figure 3 illustrates the progress and interaction of program activities from the postulated go-ahead date of January 1, 1967, to the 1971 Mars launch window (5/10/71 through 6/29/71). Development of subassemblies and components is limited to approximately one year. This limitation allows time for payload and flight system test programs using final configuration hardware and beginning 1½ years prior to the operational mission.

A limited effort is indicated at the outset for completing system specifications and tuning the design to requirements of a specific set of mission operational requirements and constraints. The chart shows overlap of some aspects of the engineering model, prototype, qualification unit, and final unit phases. This overlap is possible and necessary to compress the overall schedule.

It has been assumed that the altimeter would go aloft on a "free ride" basis in a lander earth entry mission during system-level testing. A separate flight test program is not felt to be justified. Such a program would yield little if any useful information beyond that obtained by ground testing.

JAN. 67

Go AHEAD

MISSION  
CONSTRAINTS

PAYLOAD  
CONTRACTOR  
PERSON

SYSTEM  
SPECIFICATIONS

NASA  
LIAISON





1 JUN, 68

1 JUL, 68

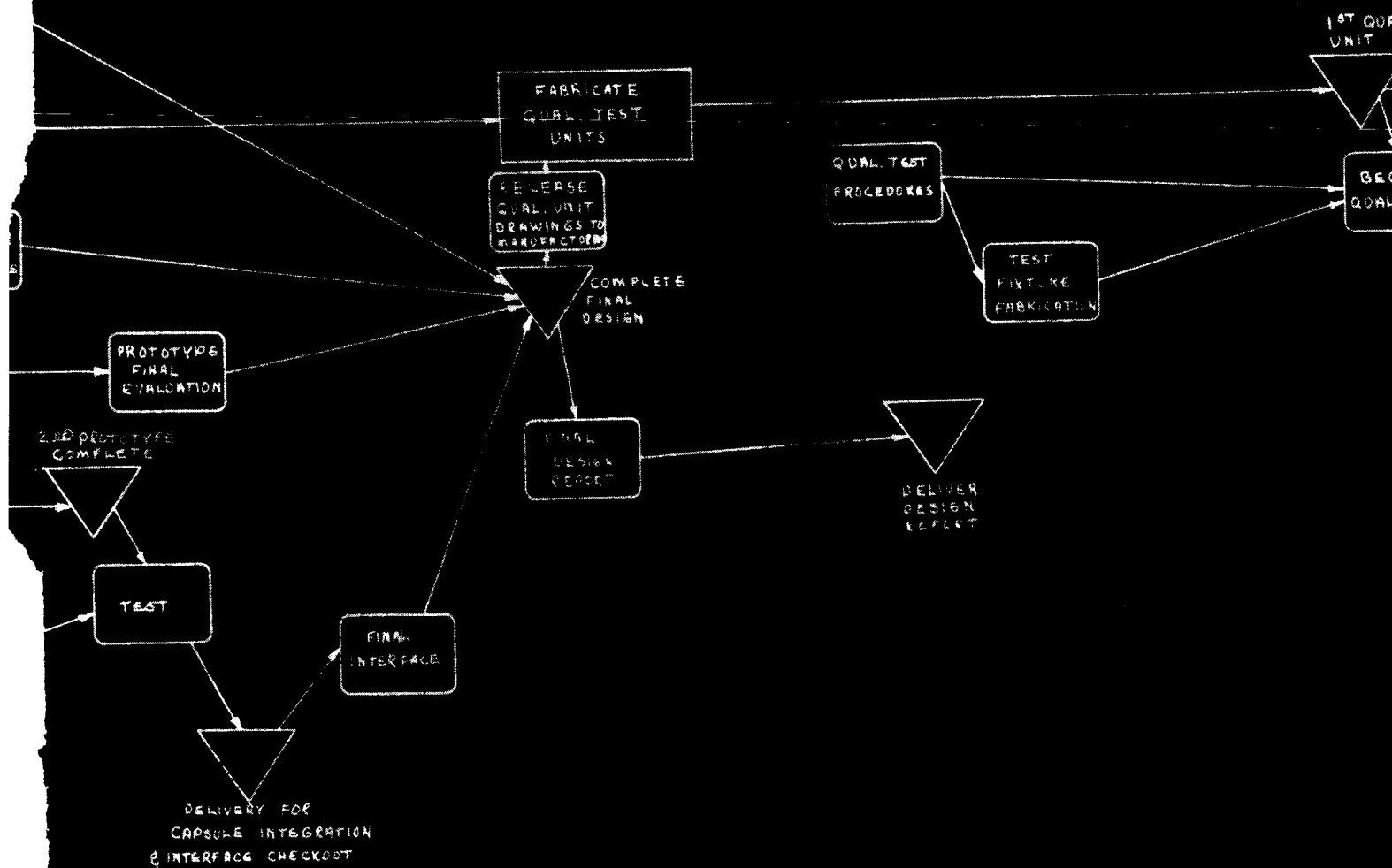
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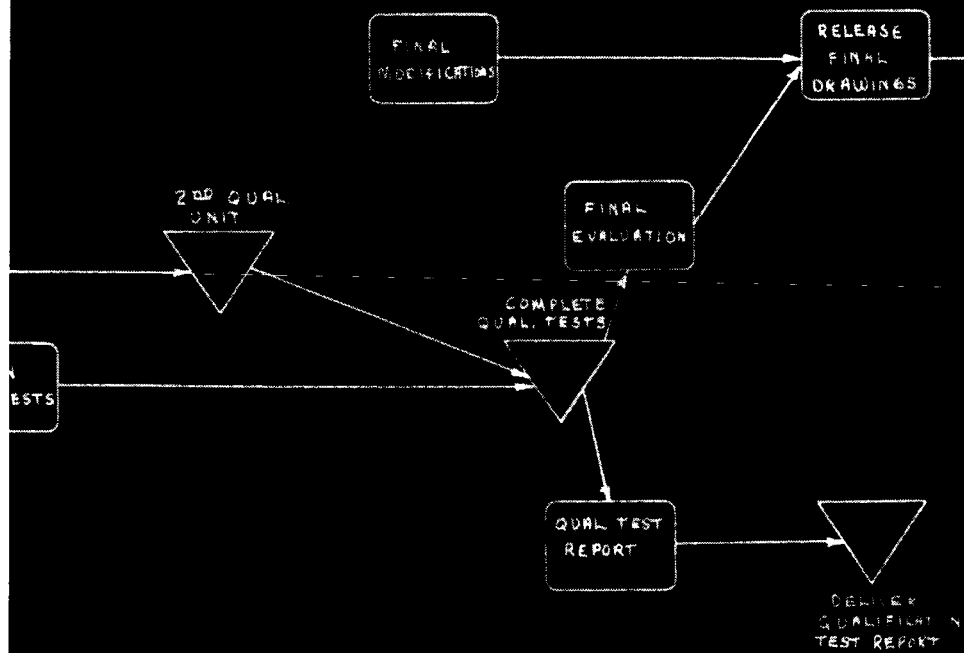
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1 DEC, 69

1 JAN, 70

1 FEB, 70

1 MAR, 70

1<sup>ST</sup>  
FINAL UNIT

2<sup>ND</sup>

3<sup>RD</sup>

4<sup>TH</sup>

5<sup>TH</sup>

6<sup>TH</sup>

ACCEPTANCE  
TEST

RECEIVED  
6<sup>TH</sup> UNIT

PAYLOAD  
INTEGRATION  
& TEST

ACC  
T

8, 70

1 APR, 70

1 MAY, 70

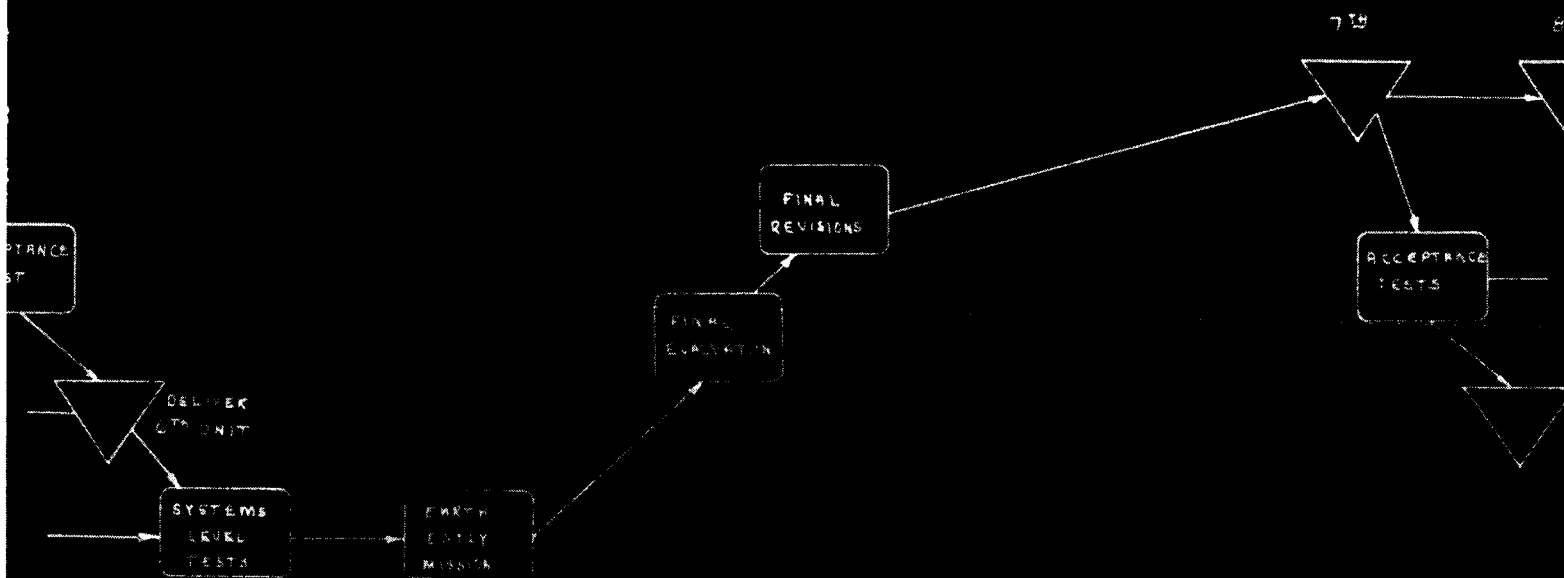
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1 DEC 70

1 JAN 71

1 FEB 71

1 MAR 71

1 APR 71

1 MAY 71

NOTE

NOTE

ACCEPTANCE  
TESTS

DELIVER  
TO THE UNIT

PAYLOAD  
INTEGRATION

FINAL TESTS &  
TERMINAL  
STERILIZATION

LEAD IN



## MANAGEMENT PLAN

With one exception, the six major contributing areas are given in the following sections. The exception, the Reliability and Quality Assurance Plans, are presented in Volume III under that title. The plans for the remaining areas have been divided into Management, Engineering, Manufacturing, and Environmental Qualification Test, and are presented in this and the three subsequent sections. The scheduling shown in the previous section applies to all plans. Cost information follows at the end of this volume.

### Program Manager

To meet the SPRA program objectives, a management team will be established and operated under the direction of a Program Manager. The responsibilities of the Program Manager include the direction, coordination, and control of all program activities of the program management organization, and also of all line personnel provided him from within the functional departments. He establishes and directs detail plans, budgets, and schedules for the major divisions of work, and he continually assesses progress made in relationship to technical, cost, and schedule objectives. The Program Manager directs particular attention to the meeting of equipment performance and reliability goals. He continually predicts and forecasts problems, slippages and accelerations of phases to top management of the Aerospace Division, and he institutes procedures to offset the problems which arise. It is also his responsibility to establish and maintain an effective line of communication with NASA during the program.

### Configuration Control Procedures

The Program Manager is responsible for management of the altimeter configuration. He determines configuration management requirements and procedures. During the early development stages, emphasis is on identification and control of the specifications and drawings defining interface between the altimeter and other payload subsystems. During the later period of the development the problems of managing the configuration of the production equipment are anticipated, and he carefully identifies and controls all end items making up the equipment.

At this point a Configuration Control Board is established. The Program Manager acts as chairman with representation from Engineering, Manufacturing, and Product Reliability. The Board assumes responsibility for the formulation, issuance, and maintenance of all configuration management documentation. All revision notices to specifications and drawings must be approved by the Board before they can be incorporated.

### Documentation

A function of the Management organization is to plan and follow the preparation of all contractual documentation. Delivered documents will



include the following:

- 1) Revised Planning Document - an updated version of the Program Plan reflecting any scheduling adjustments or performance requirement changes necessary to accommodate a specific mission.
- 2) Specifications
  - . Altimeter system specification and interface definition
  - . Submit specification
  - . Subcontract and purchased part specifications
- 3) Approved Parts List
- 4) Reliability Apportionment Report
- 5) Engineering Model Mechanization Report
- 6) Engineering Model Test Report
- 7) Reliability Estimate
- 8) Failure Effects Analysis
- 9) Prototype Design Report
- 10) Prototype Drawings
- 11) Failure Reports
- 12) Design Review Reports
- 13) Final Mechanization Report
- 14) Qualification Test Specifications
- 15) Acceptance Test Specifications
- 16) Test Reports
- 17) Monthly Status Reports
- 18) Final Report



## ENGINEERING PLAN

### Engineering and Reliability

The altimeter engineering task encompasses the two basic elements of system engineering and system design. The system engineering task addresses itself to system requirements as determined by mission objectives, to proper consideration of the interface with other payload subsystems and to providing data for proper configuration control. The System design task stresses the importance of meeting performance and physical characteristics goals.

Proper planning and organization alone will not assure successful completion of the project without adequate monitoring and liaison. Design engineers must have the opportunity to discuss their designs with other experienced engineers. They must also follow the test program for their components. Support of the manufacturing and logistics programs is included in the engineering task.

Reliability plans are discussed in detail in Volume III. However, because of the interplay between reliability activities and other engineering functions, it is appropriate to mention the reliability effort here. The Reliability Engineering group has the authority and organization necessary to provide effective control of reliability during all phases of the program. The primary responsibility of this group is to provide for reliability during design and development by defining and interpreting contractual reliability requirements and by providing specialized consultation and assistance to design personnel. Timely recommendations to all other departments are made throughout the program to assist in meeting reliability requirements.

### Program

The first portion of the program will be devoted to confirmation of system requirements, detailed definition of interfaces, and generation of detailed subassembly specifications. Subassemblies will be breadboarded for the engineering model and subcontracts will be let. The primary function of the engineering-model phase is to prove proper electrical integration of subassemblies and performance under laboratory and temperature environments. Concurrently, mechanical layout and thermal design will begin for the prototype.

Initial thermal studies and control procedures has been based upon data available during the altimeter design study: this is close enough for basic determinations. However the final analysis must be based upon the ultimate thermal conditions which will exist in the final spacecraft. Therefore a comprehensive thermal study will be performed during the prototype design phase when the spacecraft thermal control has been established. This study will ensure that all components work within their acceptable range and that only the necessary minor thermal design changes are made in the altimeter.

Although the basic packaging design has been arrived at prior to the hardware development program, certain specific details of that design will

have to be defined during the prototype phase. Several factors contribute to this: (1) advantage should be taken of the latest technique advances; (2) final altimeter and antenna configuration and placement must be based on the spacecraft design; (3) electrical and mechanical interface problems must be resolved as overall design progresses; and (4) some areas require more depth of investigation than is possible during the study period. Examples of details that must be resolved during the prototype period are:

(a) Antenna Window - The engineering group must select and test the most promising candidate materials. Although it has been assumed that the radome will be a part of the heat shield, support will be given the heat shield contractor.

(b) High Voltage Arcing - Possible arcing of the TWT high voltage must be prevented by proper design of the HVPS modulator-TWT interface plus suitable encapsulation. Models of candidate designs will be built and tested to assure proper protection.

(c) Integrated Circuit Interconnection - Within the same basic packaging concept, several interconnection techniques are possible. Although the most promising technique has been selected during the current study, this area should be reviewed before the design is released for manufacture.

(d) Magnetic Stray Field Compensation - Compensation is recommended to prevent the TWT magnetic field from interfering with the magnetometer. This is a "line of sight" function, and can be established only when the spacecraft configuration has been set. Mechanical mock-ups must be tested to ensure good isolation.

Prototype configuration will be as identical as possible to the final models. This policy will reveal problem areas at an early stage and will simplify the transition to production of final units. One of the two prototypes will be used for comprehensive bench and temperature testing. The second will be delivered for payload integration for checkout of mechanical and electrical interfacing. Necessary changes will be incorporated in the qualification test models, testing of which is described in the Environmental Test section.

Engineering liaison will be provided for the qualification program and for fabrication and testing during the remainder of the program.



## MANUFACTURING PLAN

## Organization

The Director of Manufacturing has total responsibility for the fabrication and assembly of all retained and deliverable altimeters. Responsible to him are the manpower and facilities of the Aerospace Division Manufacturing Department required for and allocated to the SPRA program. A staff of specialists, acquired from the functional subsections of the Manufacturing Department, provides additional administrative and technical assistance as necessary.

Figure 4 shows the organization of the department and its interrelationship with the Program Office. The Director of Manufacturing and his staff participate in design reviews to ensure that the design is compatible with good manufacturing practices. In addition to his regular duties of planning and scheduling workload, controlling manufacturing expenditures, and assuring that all manufacturing-related contractual obligations are satisfied within cost and delivery parameters, the Director of Manufacturing:

- a) Assists Manufacturing Department heads in the planning of their activities to conform to contract requirements.
- b) Monitors the Manufacturing Department program to ensure compliance with customer requirements.
- c) Coordinates the activities of other departments such as Engineering, Product Reliability, Purchasing, Accounting and Industrial Relations in all phases affecting manufacturing operations and producibility.
- d) Prepares for the Program Manager various status and summary reports relating to all phases of the Manufacturing program.
- e) Recommends and directs appropriate actions brought about by changing conditions of manufacturing development and customer requests.
- f) Reviews and recommends manufacturing actions relative to schedules, facilities, tooling, costs, and engineering changes.
- g) Recommends second-sourcing and subcontracting where applicable.
- h) Develops and assists in special programs of training and certification with a view towards extra motivation of involved personnel.
- i) Directs the placement of purchase requests to Purchasing for all material and purchased parts required on the Program.
- j. Maintains ultrareliability-oriented working conditions and parts control.



- k) Directs the preparation and maintenance of all manufacturing records such as stores issues, receipts, cost reports, configuration control, product reliability control, schedules, and purchased and subcontracted parts records.

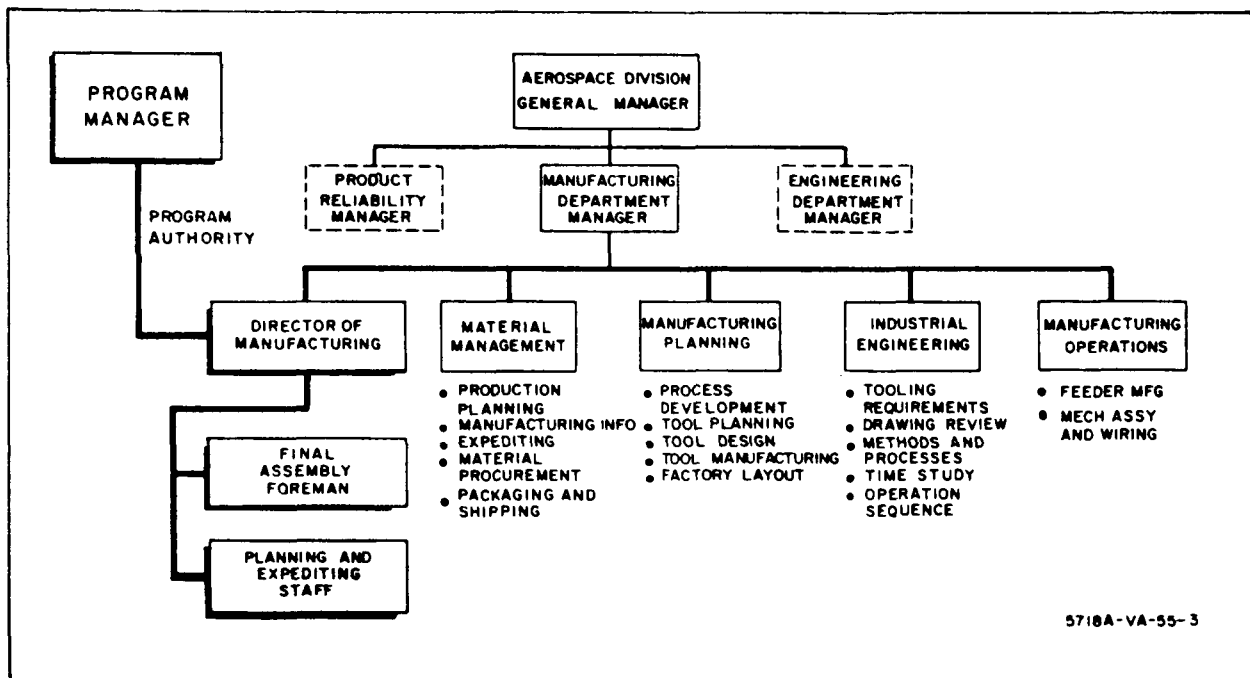


FIGURE 4. - MANUFACTURING DEPARTMENT ORGANIZATION

As the program changes from the prototype and preproduction phases into production, the manufacturing organization will change but slightly, primarily through the gradual addition of specialists from functional departments as dictated by the program needs. This will ensure production continuity in the transition from development to full production delivery rates.

Directly responsible to the Director of Manufacturing will be a Foreman of Assembly and a Supervisor of Production and Planning. During the prototype and preproduction phases, this will be minimal staff commensurate with the required effort. Moving into the production phase, the staff will be increased and areas of responsibility assigned to individual foremen by subassembly breakdown.



## Facilities and Tooling

The radar altimeter will be fabricated using the Westinghouse Quick Reaction Capability. This approach makes full use of the universal approach to fabrication and reduces the amount of hard tooling required. In addition, this approach facilitates the fast reaction for the changing needs, engineering or manufacturing, that are so necessary for successful schedule compliance.

In-Plant Facilities. - The Aerospace Manufacturing Department provides shop capability which includes machining of parts ranging from the more complex precision parts to the less critical parts. Capability exists to perform machining (turning, milling, grinding, drilling, boring, forming, piercing, etc.) of ferrous and nonferrous materials to the exacting tolerances required for the altimeter. No component parts or feeder items will be manufactured in-house that can be more readily procured at a lower cost.

Westinghouse equipment covers the needs of universal short-run, prototype and preproduction phases of the Radar Altimeter; also high volume requirements. Included are standard machine tools, and semiautomatic and automatic tape-controlled equipment. Schedule and volume requirements of the altimeter would dictate the exact equipment to perform a particular operation. Aerospace also has the facilities and experience to perform extremely accurate mechanical assemblies.

Welded Module Assembly - - Westinghouse has developed the facilities and procedures of high density packaging for welded electronic modules. Although these techniques are new and advanced, they are now standard operating procedures at Westinghouse and are readily adaptable for the interconnection of the altimeter Ceramic Integrated Circuit (CIC) Packs. All phases of module manufacture are performed in-house and include film printing and punching, component assembly, machining and plating of terminal pins, ribbon performing, welding, molding of shells and headers, embedment, and tape controlled testing. Encapsulation, embedment, and potting are performed in an area completely equipped for all types of environmental protective molding. Automatic mixing and dispensing machines handle filled and unfilled materials and can pour under vacuum if required. Ovens for preheating single as well as multicycle curing are precision controlled. The foregoing facilities will be used for the manufacture of assemblies requiring welded interconnection. The module assembly area is contained within the printed circuit facility.

Printed Circuit Facility - - This 20,000-square-foot facility has the most modern equipment for printed circuit board fabrication, assembly, and test, with a production capacity of 30,000 boards per month. The area is environmentally controlled, with recessed lighting and tile floor to reduce product contamination. The various operations of the process are performed in separate rooms.

Integrated Circuits - - The CIC Packs will be fabricated and assembled in a clean room (other than that used for Final Assembly) of the 100,000 level. It will contain all the facilities necessary from etching the circuits on the ceramic bases to performance of assembly and test operations.



Final Assembly and Test - - Clean room manufacturing and test environments are available at Westinghouse for use on the SPRA manufacturing program. Clean rooms are isolated from manufacturing processes that might cause environmental contamination. The clean room allotted to and reserved for the Radar Altimeter is under rigid environmental control and meets the requirements of Federal Standard 209 - Class 100,000 Clean Room. This room is air conditioned to maintain a temperature of  $70 \pm 2^{\circ}\text{F}$ , and a relative humidity of  $45 \pm 5$  percent. Dust counts are performed on a regular basis and access is controlled and limited. Before entering the clean room all SPRA parts and materials will be cleaned and inspected in special receiving areas. Controlled environment storage areas will store all parts and materials that enter the manufacturing process in this clean room and other assembly areas.

New Equipment. - A review of the proposed SPRA design and packaging reveals the need for some new equipment which is presently being installed and will be complete before the end of 1967. The processes and procedures for fabricating assemblies of the CIC Packs have been developed and Production facilities will be available as stated above. A listing of those major items required for these assemblies is as follows:

- a) Thermo-compression wire bonder and hydrogen generator.
- b) Resist spinner
- c) Resist applicator
- d) Mask alignment machine
- e) Vacuum bake oven
- f) Bake oven
- g) Spray etcher
- h) Plating tanks
- i) Spray developer
- j) Ultrasonic vapor degreaser
- k) Ultrasonic cleaner
- l) Package sealing machine
- m) Microscopes
- n) Miscellaneous hot plates, timers, desiccators, and small tools.
- o) Clean room (100,000 level)
- p) Film sizer
- q) Fixed reduction camera and exposure unit
- r) Die bonder

Facility Availability. - The Radar Altimeter will be produced in the Aerospace Division Manufacturing facility at the Friendship Airport site of the Westinghouse Defense and Space Center. The majority of the feeder items will be manufactured in-house. The factory floor space, facilities, and other capital equipment required, already exist and will be available in the time periods required. The altimeter production has been planned, and the layout of factory feeder, assembly, and test areas indicates that capacity for the quantities of those requested is available.

Production capacity of the Aerospace Manufacturing Department is measured in terms of production employees and shift-basis. Existing capacity is 4500 production employees on a three-shift basis. Maximum



capacity of the Aerospace Manufacturing facility can be effectively expanded by other assets of the Westinghouse Defense and Space Center complex, such as the Surface and Underseas Divisions. Present and anticipated loading conditions ensure availability of facilities to adequately accommodate the altimeter program.

Figure 5 depicts the flow of work and materials from incoming inspection through feeder manufacturing, subassembly, assembly, test, and shipping. The parts and assemblies in the manufacturing cycle flow in an orderly manner from operation to operation.

Tooling. - The Quick Reaction Capability minimizes the need for hard tooling. Only such tools as molds will be fabricated. Most parts will be fabricated from Universal setups. Assembly tools will be used only where dimensional or handling requirements dictate their needs.

### Production

Manufacturing Methods. - Tried and proven manufacturing methods will be used to fabricate the radar altimeter. Westinghouse has experience in all of the latest techniques for fabricating and assembling high-reliability electronic space equipment as well as airborne equipment. Because of this background, no new or unusual manufacturing techniques, other than those highlighted in the Chip Assembly Clean Room, will be required to accommodate the design of the Radar Altimeter.

Material Flow. - Figure 5 illustrates the material flow of raw materials, purchased parts, and fabricated parts and assemblies with the respective inspection points. To maintain proper control of parts and assemblies, a project storeroom will be established for the storage exclusively of SPRA purchased parts and raw materials.

Production Control. - Production control will be responsible for material control, product follow, dispatching, and the co-ordination of those items common to the Product Reliability and Manufacturing Departments. The value and complexity of components dictate close and stringent material control. Reliable, efficient, and on-schedule fabrication and assembly of the Radar Altimeter will be assured by the availability and use of one of the most advanced manufacturing control systems in the Aerospace Industry. This Westinghouse Mechanized Production Control System is a means of maintaining complete and effective control of the flow of all work and current status of all fabricated items on a daily basis at each work station.

This mechanized system captures all pertinent information such as contract charges, part numbers, quantities, and operations on punched cards. Separate cards are created for each operation required by the Standard Instruction Sheet (SIS). Each altimeter item fabricated in the Aerospace Division Shop will have a job pack (system cards and SIS) created for and associated with it. Shop production control releases the job pack to the storeroom for release of the raw material as scheduled by the planning group. When the material is released to the first operation, the Production Release Card is pulled from the job pack and submitted back to shop production control for updating the master file.

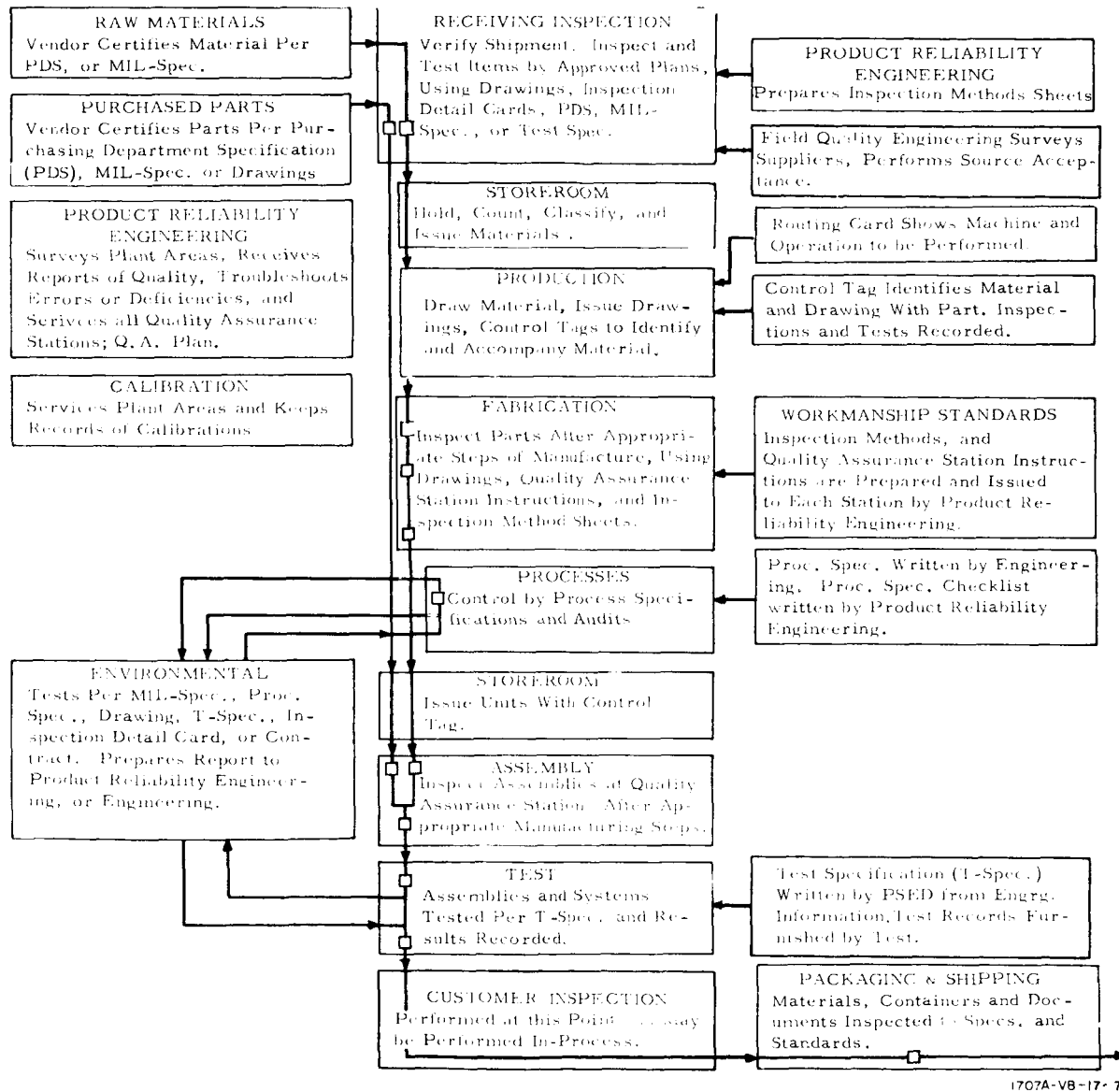


FIGURE 5. - MATERIAL FLOW



Upon completion of each operation, the material, job pack, and drawing are submitted to Product Reliability inspection. If the material meets the requirement of the drawing and SIS, the inspector will approve the operation on the Inspection Control Card and the Pay Card. The Inspector then dials into the IBM 357 Input Station such variable information as setup time, run time, and quantity. This information and the other information on the Pay Card is transmitted via cable to an IBM 026 Output Station in the Shop Production Control Office. The output station creates Production Control 357 Output Cards which are submitted to the computer operation on a daily basis for the creation of daily and weekly status reports. After the operation is paid off, the material and the balance of the job pack flow through all other sequential operations called out on the SIS until completion. At that time it is entered into the Work-in-Process Inventory System using the Storeroom Receipt Card.

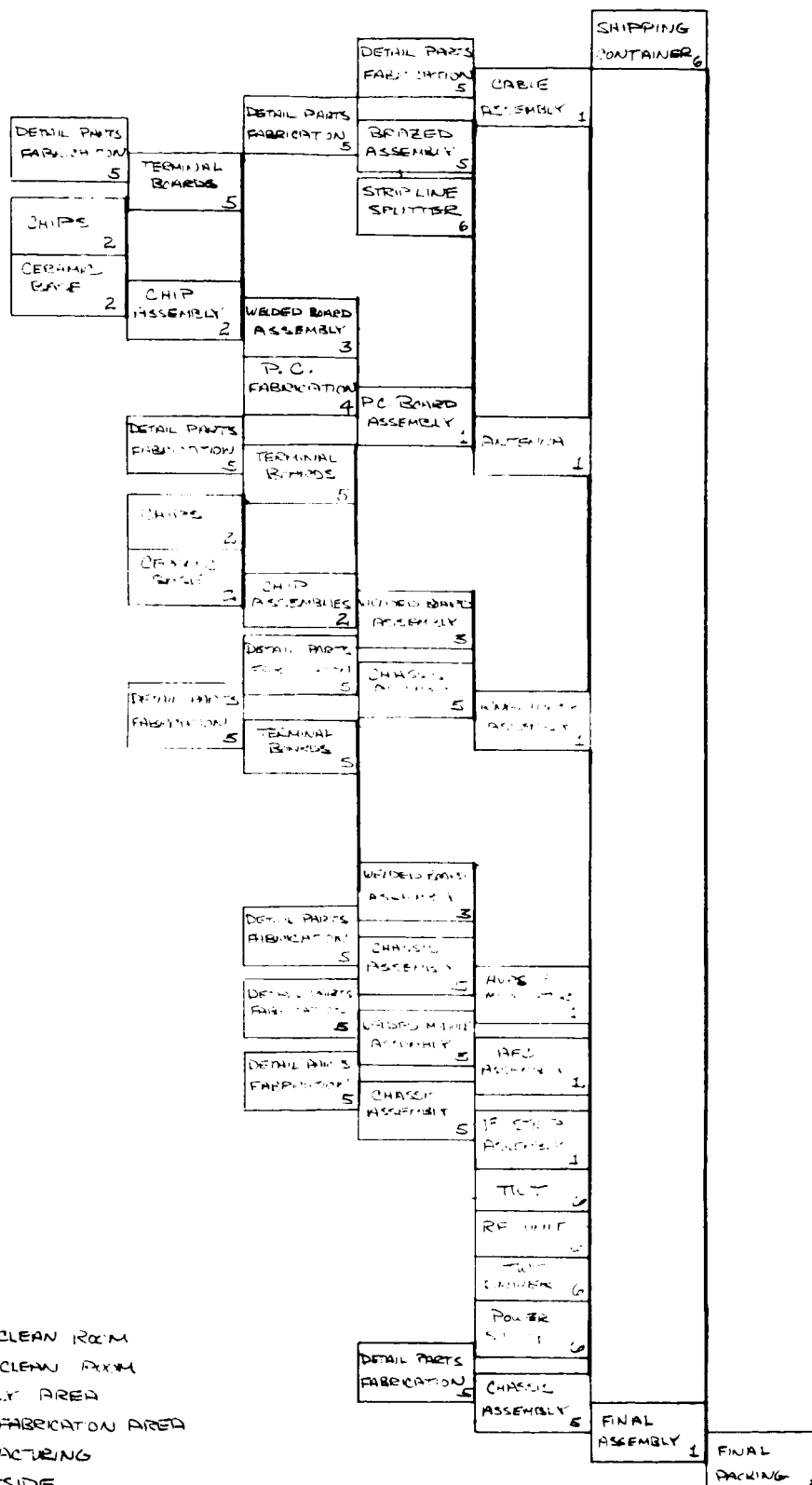
The daily labor efficiency and schedule status reports created by the 357 Output Cards update the Shop Production Master file. These reports are also used by the Production Department (a) to determine the status of the job as compared to the overall master production schedule, and (b) to review the job with shop manufacturing people during bi-weekly meetings and to make decisions as to production splits, critical items, overdues, etc. In addition, the Accounting Department uses all labor information control output cards to charge the applicable labor hours to the various contracts.

Using the Production Master File, it is possible to obtain Contract History, Cost-to-Complete, Schedule Status, or Section Loading as required. Thus, Management has the data necessary to identify work-in-process status inefficiencies and to facilitate the preparation of program visibility aids such as the Line of Balance. Using these tools, Management is able to cope with situations as they occur.

Flow Chart. - Both purchased and manufactured parts are stored and controlled from clean rooms. Parts requiring assembly outside this area are cleaned prior to their return, thus maintaining the cleanliness level of the particular clean room involved. A logical flow of altimeter parts is depicted in the flow chart of Figure 6.

Materials Handling. - The following are typical procedures for handling Space-Categorized Assemblies:

- 1) Project personnel release production material from project storerooms.
- 2) Each release is packaged for best protection. Parts and components are packed in individual plastic bags and separated dividers as required to prevent contact damage. Each release is packed in a standard plastic tote box and sealed with a clear plastic dust cover for contamination protection during transportation and preassembly storage. Product Reliability seals the tote boxes.





3) Production provides material inspection lot-number information with each release. Individual materials must be identified by lot number. Identical parts that have different lot numbers are kept separate.

4) Project Production supplies a separate Control Sheet for each assembly in the release, and records the following information on the sheets:

- a) Serial number assigned by project personnel;
- b) Drawing number, revision of drawing, M-number and any outstanding revision notices including break-in point, and the appropriate process specifications: and
- c) Drawing and item number or identification number of all material required. The Control Sheet physically accompanies each assembly throughout the entire manufacturing cycle. All entries are typed or written in ink. Additional sheets if required are stapled to the original.

5) Projection Inspection verifies that the release agrees with the foregoing requirements. They affix signature, stamp, and date on the Control Sheets, and attach the seal to the tote box plastic cover. This seal is broken only by the next operation Area inspector.

#### Assembly

Clean Room Assembly Area.-The clean room will be the control point for materials, subassemblies, and assemblies for his program. The final altimeter assembly, the system electrical performance tests, and all Flight Acceptance tests will be made in the Class 100,000 clean room. This precaution, plus the reduction in microorganisms as a side effect of the Sterilization/Decontamination compatibility tests, combine to ensure that the terminal sterilization procedure will be effective.

Clean Room Control. - To establish and maintain a Class 100,000 clean room, numerous requirements are imposed on the area, equipment, personnel, materials, controls or operating procedures, and maintenance techniques. A complete listing of these requirements appear in Appendix A. Examples of these, however, are controlled air conditioning and room pressurization, traffic control and adhesive floor mats at entrance, and specification of allowable wearing apparel.

#### Shipping

The completed and tested flight hardware will be placed in its shipping container while in the Class 100,00 clean room. This container will be designed to maintain the clean room environment to the point of delivery.



## TEST PLAN

This section generally describes the qualification test plan to be applied to the Space Probe Altimeter

### General Conditions

In general the planned qualification tests will meet the requirements of MIL-STD-810A (Military Standard Environmental Test Methods for Aerospace & Ground Equipment). However, special environmental considerations will be patterned after the Jet Propulsion Laboratory Specifications 30250B (Environmental Specification Mariner C Flight Equipment Type Approval Environmental Test Procedures) and VOL-50503-ETS (Environmental Specification Voyager Capsule Flight Equipment Type Approval and Flight Acceptance Test Procedures for the Heat Sterilization and Ethylene Oxide Decontamination Environments). Whenever possible the vibration and dynamic loads will simulate those loads experienced on the Saturn IB/Shrouded Centaur booster.

### Test Specification

Detailed test specifications and procedures for performing the planned qualification test program will be prepared. These documents will establish specific test parameters, data acquisition and analysis procedures, and test setup criteria.

### Mechanical Inspection

Before and after each environmental test, the test specimen will be inspected to determine any physical discrepancies resulting from handling or testing. This inspection will be visual at ambient laboratory conditions. Equipment will be inspected for failures, discrepancies, or indications of discrepancies including the following: Correctness of equipment configuration, cleanliness, discoloration, moisture, corrosion, dents, scratches, chips, fractures, and loose parts.

### General Performance Checks

Pretest/post-test performance check. - This check will provide test-specimen performance evaluation to expose any degradation which might occur during environmental testing. The test specimen will be operated before and after each environmental simulation.

Performance check. - If the detailed specification requires the equipment to operate during the environment exposure, then performance will be checked during the environmental test. During the tests which simulate descent, the test specimen will be operated to verify performance parameters.

### Qualification Tests

Thermal vacuum. - Westinghouse plans thermal vacuum tests to realistically simulate launch, space flight and descent. These tests will be performed in lieu of the high-temperature low-pressure tests advocated in MIL-STD-810A,



and should more nearly simulate the environments to which the altimeter will be exposed. The temperature of the altimeter will be controlled by regulating the radiative environment inside a vacuum chamber using a combination of quartz heat lamps and temperature-controlled shroud walls. To simulate launch conditions the chamber pressure will be reduced to 10 percent of atmospheric pressure in 2.5 minutes or less. The altimeter would not be required to operate under this condition but, rather, to demonstrate its survival capabilities.

The altimeter will be exposed approximately 3 days to a space environment simulation of what it will experience in the spacecraft. Then it will be turned on and operated to determine its start-up capabilities after a prolonged space flight. All electrical parameters will be checked for satisfactory operation, and the chamber pressure will then be increased to an approximate altitude of 100,000 feet. This portion of the test will simulate descent and demonstrate freedom from corona.

Prolonged Life Test. - The above procedure should provide a realistic test, and no significant information would be gained by exposing the unit to a long period of time at high vacuum. Moreover, such a test would incur additional and unnecessary costs. However, during the construction of the altimeter, materials will be avoided which demonstrate extreme vacuum outgassing.

Acceleration. - An acceleration test will demonstrate the altimeter's structural integrity during launch and its ability to survive such an environment. The altimeter will not operate during this centrifuge test but will be checked for satisfactory operation following it. The levels of acceleration will be those suggested for the Saturn IB/Shrouded Centaur booster. On the other hand, it appears advisable to test the altimeter while operating under the deceleration exposure which it would experience during the descent phase of the mission. The levels applied would be those anticipated during descent.

Vibration. - Complete vibration tests on the altimeter will verify compliance with design requirements. The applied level will be the maximum expected vibration environment for the Saturn IB/ Shrouded Centaur booster. Specifically, the levels will be those found in Marshall Space Flight Center Memorandum, MP/VE-ST-341-63, "Dynamic Environment of Centaur Stage of Saturn IB/Centaur/Voyager Vehicle," D. Parker, W. Gruner (539-0743) 7/29/63.

The altimeter will be exposed to sinusoidal cycling vibration to determine harmful resonances and demonstrate the altimeter's ability to survive the environment. Random vibration also will be applied to demonstrate its structural integrity. Both types will be applied in three mutually perpendicular axes, and an automatic equalizer will ensure spectrum shape for the random vibration. Magnetic tape will record the vibration inputs and responses for both types of vibration.

During simulated descent the altimeter will be exposed to the vibration levels determined from data obtained on the retrosystem (if any). Functional requirements will be verified during this vibration exposure. Again, magnetic



tapes will record the vibration inputs and responses. This test should demonstrate the altimeter's ability to operate during the descent phase of the mission.

Electromagnetic interference. - Electromagnetic interference tests on the altimeter will demonstrate its freedom from interference from other systems in the spacecraft. The tests will be performed above the 1 GHz frequency range in a subdivided RFI facility, the altimeter being in one area and the monitoring equipment in the other.

Magnetic moments. - Other planned tests will determine the magnitude of the moments due to permanent, earth-induced, and stray-field magnetization. Preliminary plans indicate the feasibility of using the magnetic measuring facility at the Naval Ordnance Laboratory at White Oak, Maryland. This facility has made magnetic measurements of the UK-2/S-52, S-6, and IMP satellites with determination of field magnitudes of less than 1 gamma. The purpose will be to determine if the test item conforms to the specified magnetic cleanliness required.

Shock. - Because the descent shock environment is considered a more strenuous test, Westinghouse recommends omitting the bench handling test. While it is simple to run and very low in cost the additional information obtained would be insignificant.

A 200-g, 1-millisecond sawtooth wave will simulate the shock of descent induced by the firing of pyrotechnics. The test will be applied in each of three mutually perpendicular axes. A strain-gage transducer and memoscope will verify the shock pulse input based on shock data from studies of the retrosystem.

Humidity. - Another test will be the altimeter's resistance to humidity. This will be patterned after the humidity test specified in JPL spec 30250B for the Mariner Mission. It is understood that the spacecraft normally will be required to operate only in a controlled atmosphere prior to launch; however, there is a possibility of encountering humid conditions prior to launch. Functional requirements will not be checked during the test, but will be verified at the end.

Radiation and Micrometeoroid Hazard. - Considering that the altimeter will be encased in a sterilization cannister, which in turn will be installed in the spacecraft, Westinghouse believes the radiation and micrometeoroid hazards to be negligible, and therefore testing for these parameters will be omitted.

Sterilization/decontamination. - Facilities will be provided which perform as closely as possible to the requirements of JPL Specification VOL-50503 - ETS. The altimeter will be exposed per the above specification to determine its capability of surviving the sterilization procedure.



## Equipment

Fixtures. - All fixtures necessary for holding the test specimen during the environmental exposures will be designed and built at the Westinghouse Aerospace Division.

Test equipment. - During normal altimeter operation, all operations and functional evaluation will involve a test set assembled specifically for this purpose.

Instrumentation. - Standard thermocouples and accelerometers will monitor environmental stresses. One control accelerometer will be attached rigidly on the fixture near the structure receiving the applied vibration. Two other accelerometers will be oriented with axes mutually perpendicular to that of the control accelerometer. Located near fixture-item interface, they will detect any lateral motion, or cross-talk.

During tests requiring temperature monitoring, thermocouples will be attached to the item in sufficient number and at such locations as to measure the highest and lowest critical temperatures. A calibrated ionization gage will monitor thermal vacuum chamber pressures for shock pulses of less than 11 milliseconds duration, crystal accelerometers will monitor the stress; for longer durations, strain gage accelerometers will be used.

Data. - During vibration all accelerometer signals will be recorded on magnetic tape and then recorded on an X-Y plotter. Strip chart recorders will record outputs of thermocouples. During shock tests the transducer signal will be displayed and photographed on an oscilloscope. During high humidity tests, a circular chart recorder will monitor wet bulb and dry bulb temperatures.

Facilities. - Plans are to conduct the above qualification tests at the Westinghouse Aerospace Test Laboratory. However, the high g-levels needed for the shock test require the facilities at Goddard Space Flight Center, Greenbelt, Maryland. To conform to the JPL specifications for thermal sterilization and chemical decontamination, a special facility will be purchased.

Facilities for conducting the magnetic moment tests are at the Naval Ordnance Laboratory, White Oak, Maryland.

The following list describes the facilities at the Aerospace Test Center planned for use in qualification testing.



## (a) Vibration Exciters

Name	Frequency Range	Rated Force Output	Maximum Acceleration, g	Features
Calidyne 174	5-3500 Hz	1,500 lb	75 g	Automatic frequency cycling. Servo controlled exciter level.
MB C210	5-2000 Hz	28,000 lb	81 g	Random, sinusoidal, or mixed capabilities. Automatic frequency cycling. Servo controlled with automatic equalization and analysis.

## (b) Humidity Chamber

Name	Size	Temp (°F)	% R.H.	Features
Tenney TH27	3x3x3 ft	0 to +180	3-95+	Penetration for leads.

## (c) Accelerators

Name	Max g	Characteristics
Shaevitz Rotary Accelerator	100 g	Slip ring connections.

## (d) Thermal Vacuum

Name	Size	Temp (°F)	Minimum Pressure
Bethlehem	36" dia. 48" long	-90°F to +160°F -300°F with LN <sub>2</sub>	1 x 10 <sup>-7</sup> ton

## (e) Electromagnetic Compatibility Laboratory

Manufacturer: Filtron

Size: Two adjacent rooms with one common wall.

Room #1 - 10 ft x 10 ft x 20 ft

Room #2 - 10 ft x 20 ft x 20 ft

Power: 115V, 400 Hz, 3  $\phi$ , 50A  
115/208V, 60 Hz, 3  $\phi$ , 50A  
440V, 60 Hz, 3  $\phi$ , 50A  
+28 Vdc, 50 A

Performance: Shielding meets requirements of MIL-E-4957A.

Features: Contamination control techniques control cleanliness of rooms.

Instrumentation: Radio interference field intensity meters:

Stoddart NM-10A	14 kHz - 250 kHz
Stoddart NM-20B	150 kHz - 25 MHz
Stoddart NM-30A	25 MHz - 400 MHz
Stoddart NM-52	375 MHz - 1 GHz
Polarad FI/M	1 GHz - 10 GHz

Additional Test Instruments:

Necessary calibrating generators, sine and impulse.  
Necessary instrumentation for RF and AF susceptibility tests.  
Instrumentation for measuring filter insertion loss per MIL-STD-220.

#### Failures and Retest

All failures which occur during formal qualification will be fully documented and completely investigated. Any retesting will be negotiated at the time of occurrence.

#### Reports

A final report covering all the environmental tests will follow the test program. This report will be submitted to the customer within 30 days of the program conclusion.

#### Acceptance Tests

General Conditions. - Acceptance tests will demonstrate that the hardware is ready for flight. In conformance with specification VOL-50503-ETS. These tests will be conducted in the Class 100,000 clean room used for final assembly operations.

Tests to be run. - The following acceptance tests will be performed to ensure quality.

(a) Thermal/vacuum. - A small vacuum bell-jar facility will be located in the clean room and the altimeter will be exposed to an environment as previously described under "Qualification Tests" except that the parameter levels will be reduced.

(b) Vibration. - To perform the vibration acceptance test in the clean room, a small exciter will be moved into the final assembly area. However, this exciter does not have random vibration capabilities, permitting only sinusoidal vibration. Reduced levels will be applied but in general the same procedure will be used as has previously been described.



(NOTE: If random vibration is a necessity, an alternate method would be to place a small portable chamber over the standard environmental laboratory exciter. This would provide a clean room environment, although the level would be somewhat lower than in the final assembly area, and a physical transfer would be involved.)

(c) Sterilization/decontamination. - Westinghouse will test, per JPL Specification VOL-50503-ETS, in facilities which most nearly satisfy the specified chamber requirements.



## COST AND PROGRAM FUNDING

Cost information is presented here in two ways: by the major phases (design and development, qualification, and production) and by monthly costs in six functional areas (management, engineering, reliability, manufacturing, quality assurance, and environmental test).

Table I summarizes total program costs. The design and development phase includes fabrication of a breadboard engineering model and two prototypes. All subcontract development costs are included here. The qualification phase includes the costs associated with manufacture and environmental test of two altimeters of final configuration. Production costs are for manufacture of ten altimeters plus support of the operational mission.

Quality assurance provisions in accordance with NASA specification NPC 200-2 have been assumed throughout the program.

Figures 7 through 12 show funding by months from an estimated go-ahead of 1 January 1967 through the 1971 launch period. Management costs include documentation. Engineering costs include subcontract development and materials costs for the breadboard model and the two prototypes. Material costs for the 2 qualification units and 10 delivered units are included in the manufacturing figures.

TABLE I. COST AND PROGRAM FUNDING

	Dollars (Thousands)	Design & Dev. (2 Prototypes)	Qualification (2 Units)	Production (10 Units)	Total
1) Total Direct Manufacturing Cost		106	189	942	
2) Total Direct Engineering Cost		1,447	364	444	
3) Total Manufacturing and Engineering Cost		1,553	553	1,386	
4) Independent Research and Development (3.7%)		57	20	51	
5) Total Mfg., Engr., and I.R.&D. Costs (3 + 4)		1,610	573	1,437	
6) General and Administrative Expense (9.3%)		150	53	134	
7) Total Cost (5 + 6)		1,760	626	1,571	
8) Fixed Fee (10% of selling price)		195	69	175	
9) Selling Price		1,955	695	1,746	4,396
<u>Hours (Thousands)</u>					
Manufacturing hours		5.6	5.4	26.1	
Engineering hours		117.8	33.8	42.4	

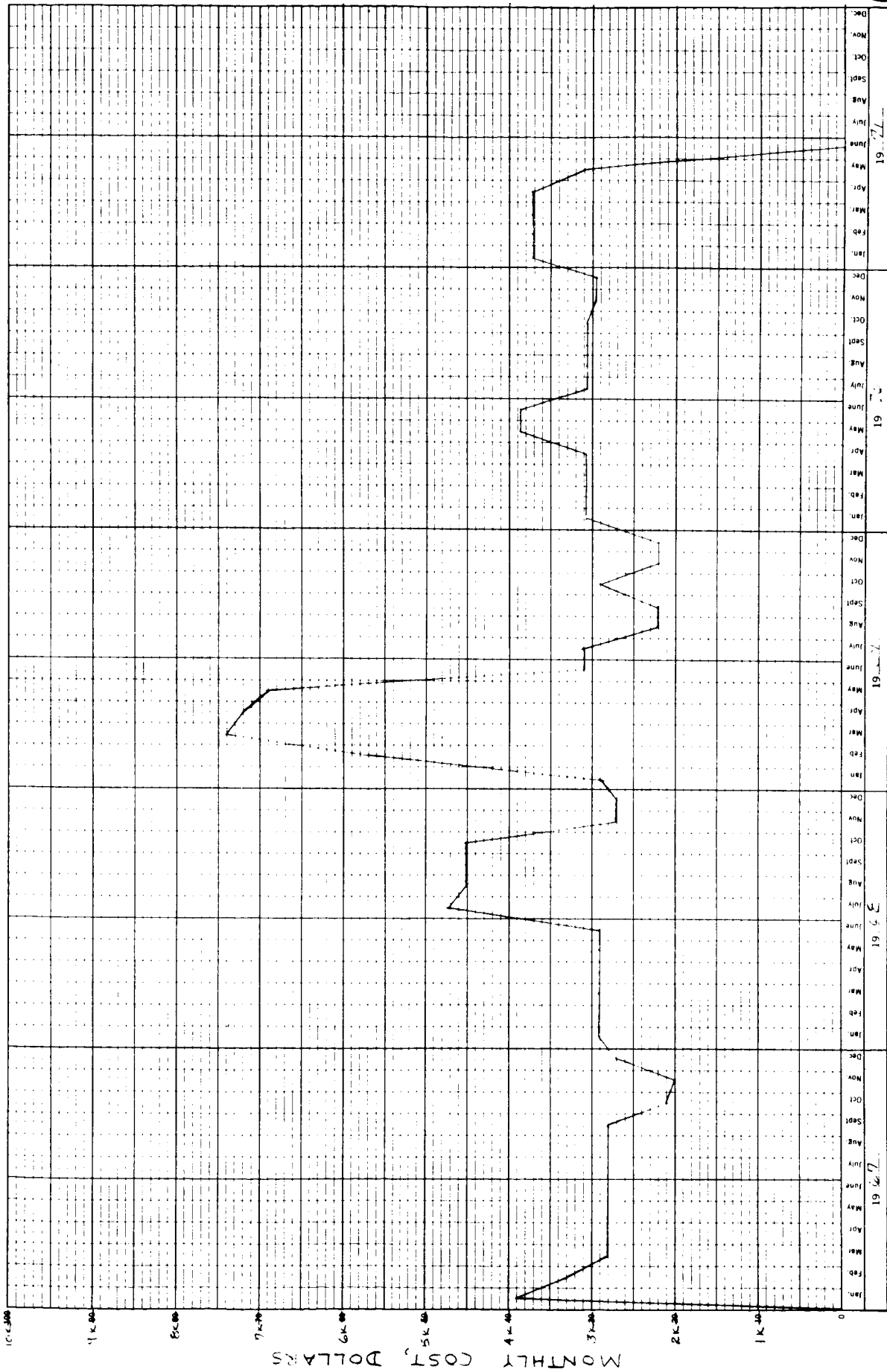


FIGURE 7. - MANAGEMENT FUNDING

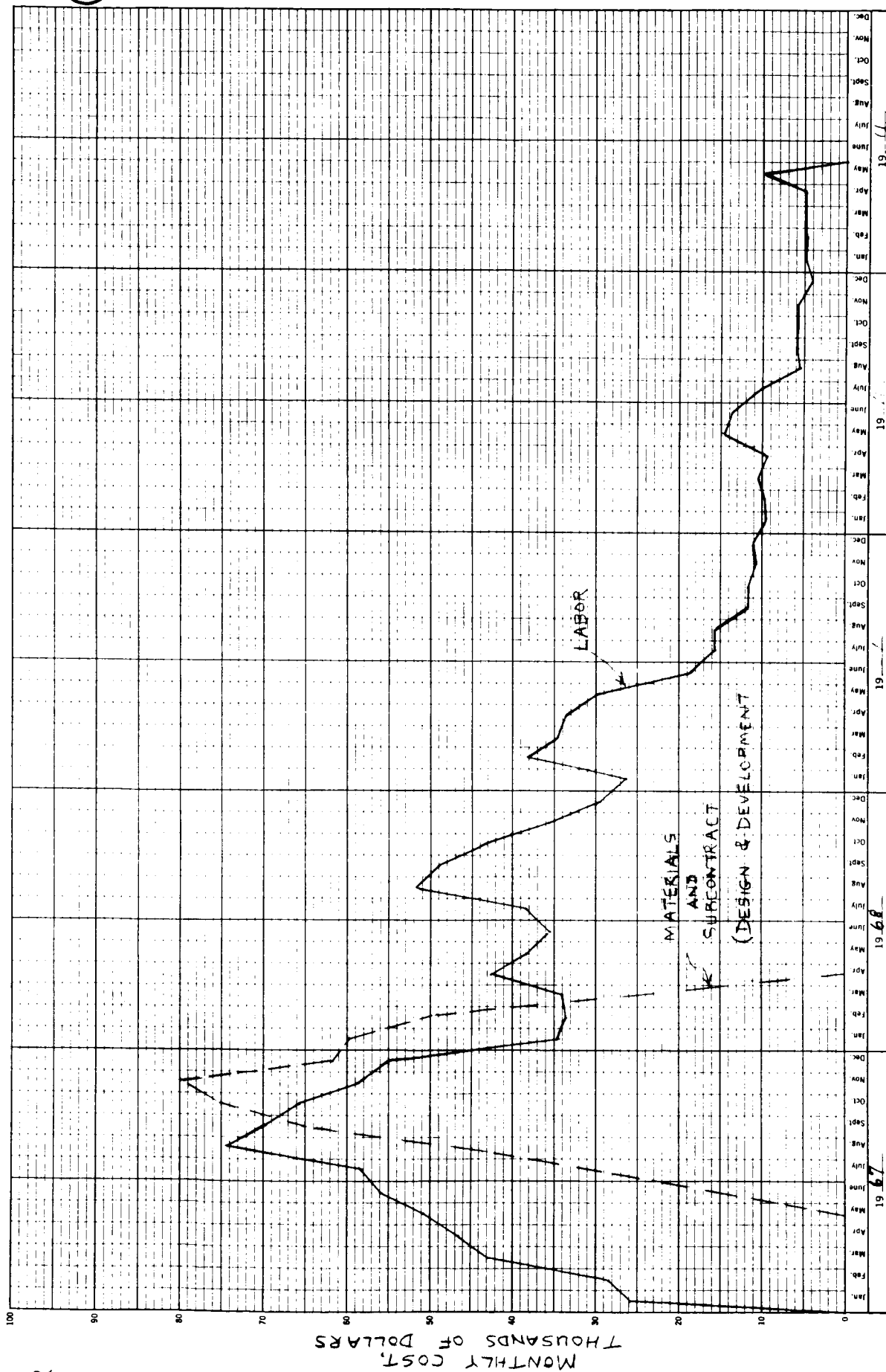


FIGURE 8. - ENGINEERING FUNDING

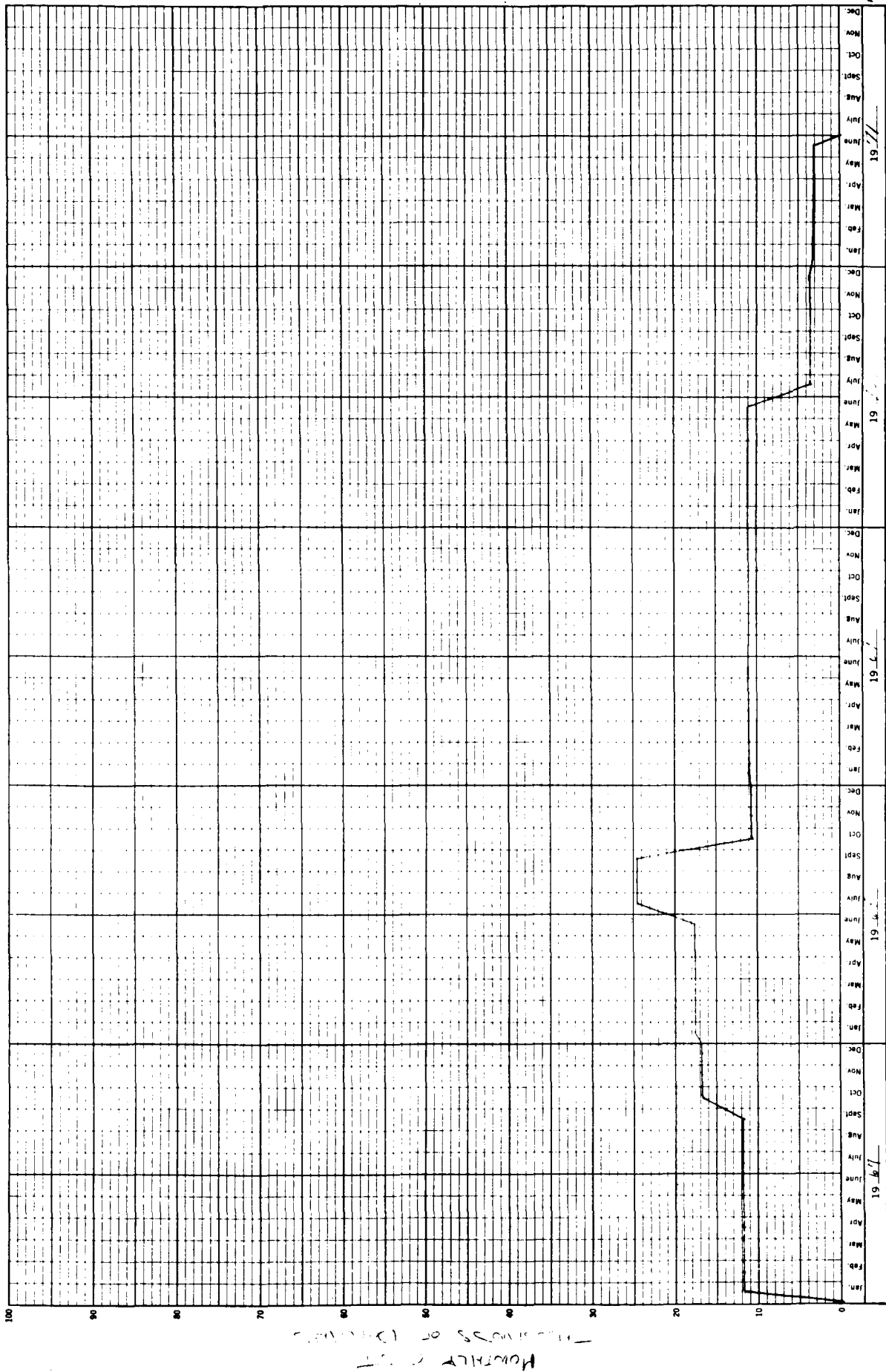


FIGURE 9. - RELIABILITY ENGINEERING FUNDING

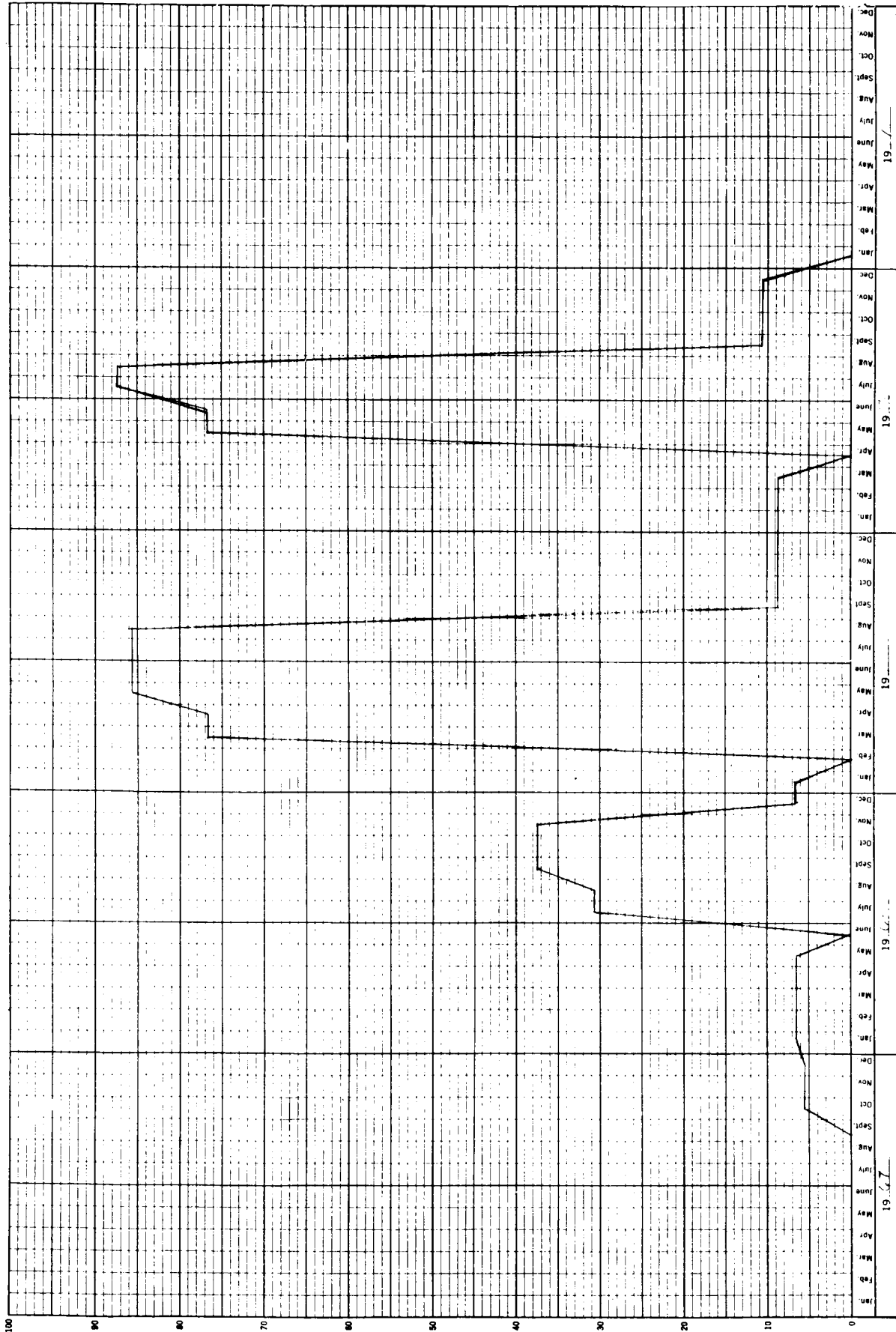


FIGURE 10. - MANUFACTURING FUNDING

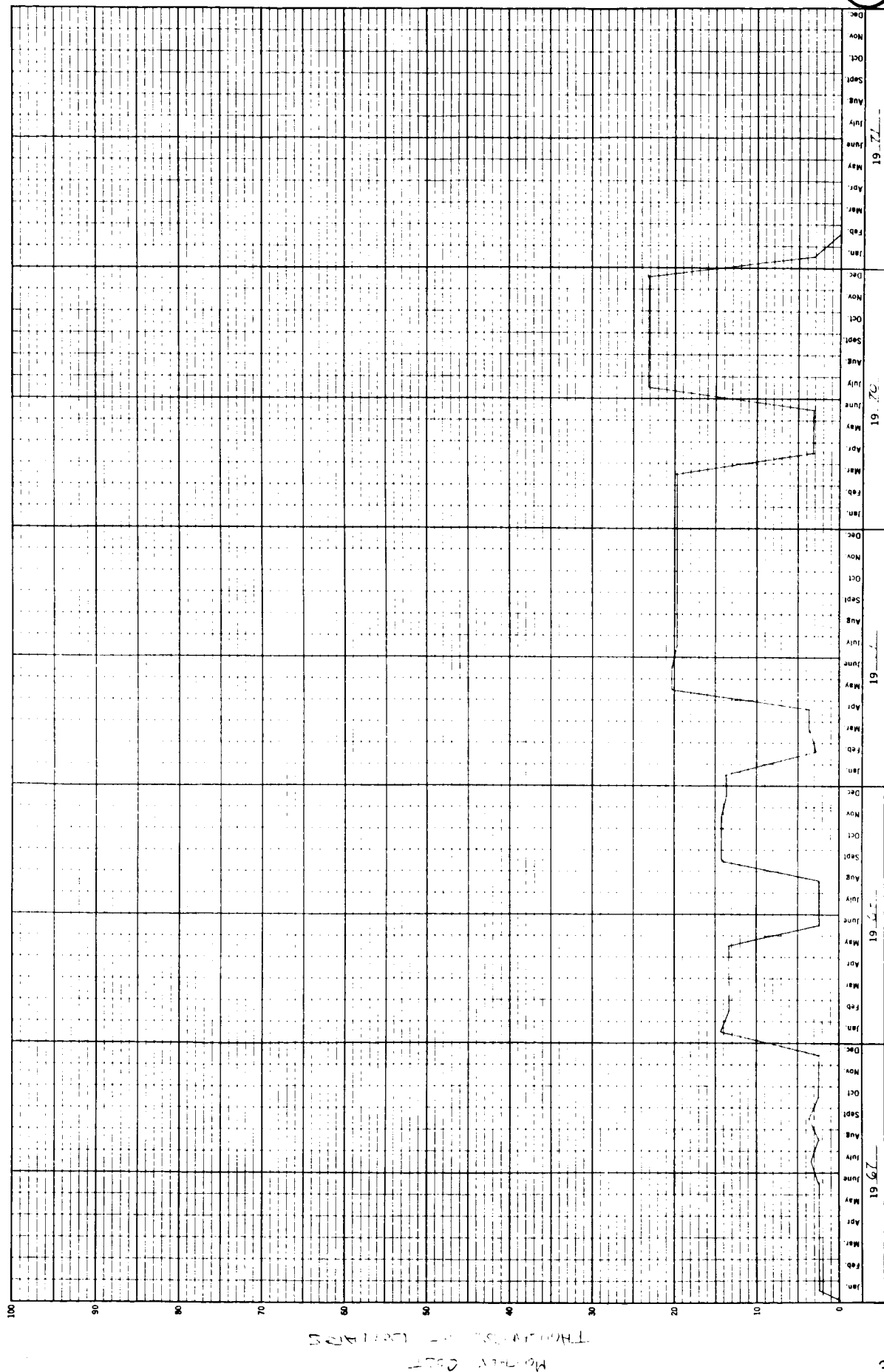


FIGURE 11. - QUALITY ASSURANCE FUNDING

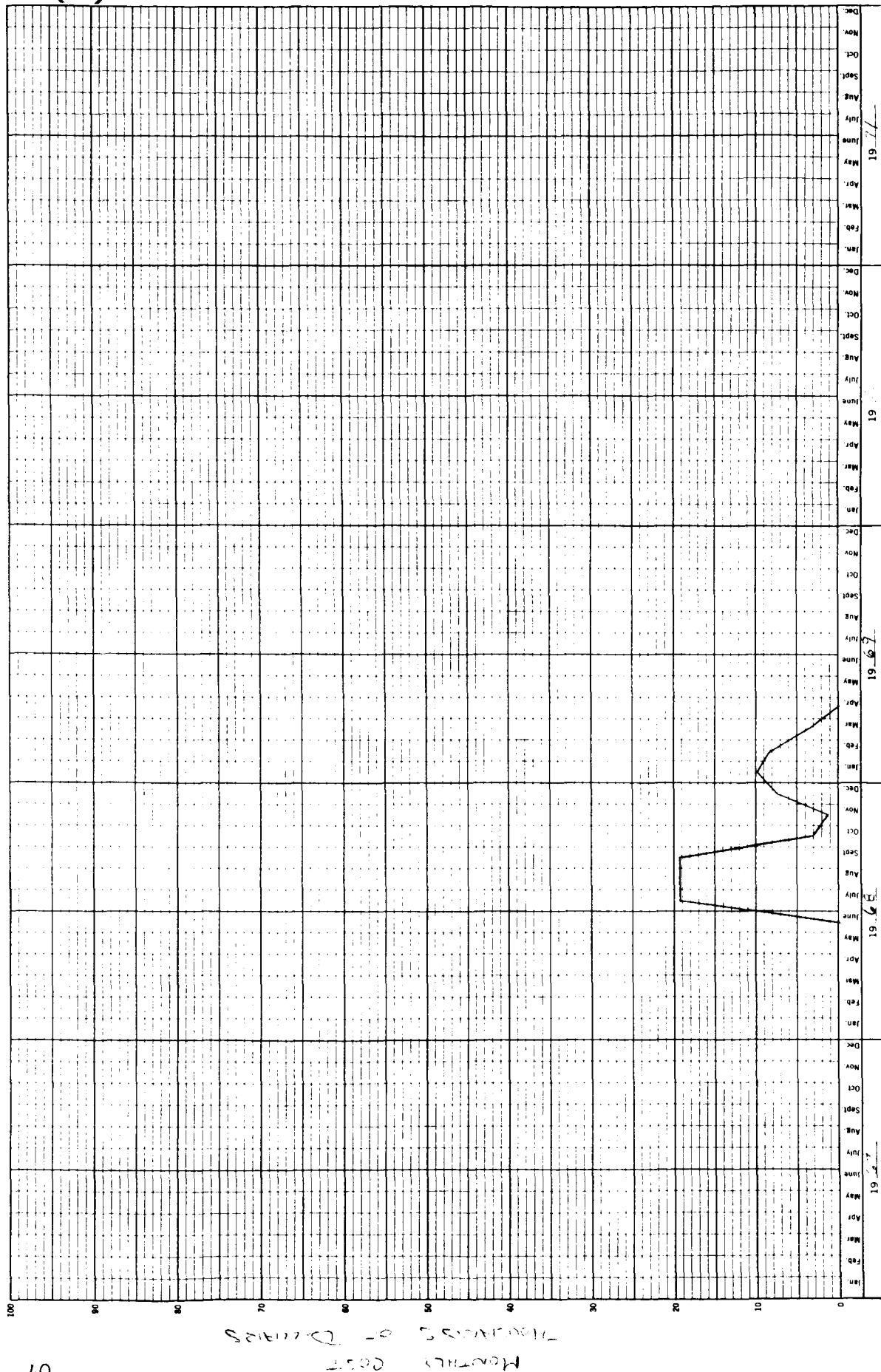


FIGURE 12. - ENVIRONMENTAL TEST FUNDING



Appendix A  
CONTROL PROCEDURE FOR  
SPACE PROJECT CLEAN ROOMS

1. Area Requirements

- 1.1 The area shall be completely enclosed.
- 1.2 Lights shall be completely enclosed.
  - 1.3 Floor shall be of vinyl or other nondust-generating material.
  - 1.4 Walls shall be easily cleanable.
- 1.5 The air conditioning system shall:
  - 1.5.1 Operate continuously twenty-four (24) hours a day, seven (7) days a week.
  - 1.5.2 Maintain temperature at  $72 \pm 5^{\circ}$  F.
  - 1.5.3 Maintain humidity below 55 percent.
  - 1.5.4 Be capable of maintaining a positive pressure with relation to surrounding areas.
- 1.6 A fixed vacuum source shall be provided, exhausted outside the area.
- 1.7 Telephone service shall be provided to minimize in-and-out traffic and to eliminate unnecessary entry.

2. Equipment

- 2.1 All equipment provided for this area shall be approved by a MPS or by the Contamination Control Committee.
- 2.2 A shoe cleaner shall be provided.
- 2.3 Gelatin or sticky paper mats shall be provided at air lock entrance to the Clean Room.
- 2.4 Calibration and similar support equipment and housekeeping utensils are to remain in the Clean Room area if possible. Necessary movements of these in and out of the Clean Room area must be preplanned to keep the number of moves to a minimum. This equipment is thoroughly vacuumed before being brought into the Clean Room Area.
- 2.5 Test, inspection, photographic, repair, etc., equipment brought into the area for temporary use shall be thoroughly vacuumed or cleaned according to manufacturer's recommendation before being brought into area.

3. Personnel

- 3.1 The Clean Room area is restricted to authorized personnel. Unnecessary personnel traffic will be discouraged.
- 3.2 These rules are mandatory for personnel visiting or working the Clean Room area.
  - 3.2.1 Smoking or edibles, including candy, chewing gum or soft drinks are absolutely forbidden in the Clean Room area.



- 3.2.2 Hair is confined in a white cap. Collars and cuffs on white lint-free coats are closed.
- 3.2.3 Dust preventative smocks and caps are put on before entering the Clean Room area. Care must be taken not to contaminate the clothing by allowing it to touch the floor.
- 3.2.4 Dust preventative clothing is removed immediately after leaving the Clean Room area. Dust preventative clothing is not worn outside the Clean Room air-lock area.
- 3.3 It is not practical to define the specific type street clothes which are allowed in the Clean Room area. However, wearing of lint-producing items such as angora sweaters or linty wool stockings is prohibited. Personnel are encouraged to wear clothing made with synthetic fibers, such as orlon, nylon, and dacron. Shoes made with ripple soles of a design which are not readily cleaned by the shoe cleaning device are forbidden.
- 3.4 Personnel performing operations where adhesion is an essential requirement (i.e., potting, encapsulating, coating) must wear clean white cotton or rubber gloves. Rubber gloves are worn during the cleaning operations and cotton gloves when handling the parts during application of compounds. Gloves are worn when handling components prior to encapsulating.

#### 4. Materials

- 4.1 Only that paperwork which is essential to the operations is allowed in the area.
- 4.2 Only those solvents and materials specially required by process specification are allowed in the area.

#### 5. Controls

- 5.1 The Clean Rooms are restricted except to authorized visiting personnel. The Supervisor is notified prior to visitors being allowed to enter the Clean Room.
- 5.2 Visiting personnel must be escorted at all times in the Clean Rooms and it is the escort's responsibility that Clean Room rules are adhered to.
- 5.3 Dust preventative smocks and caps specifically assigned for visitors use are to be put on before entering Clean Rooms.
- 5.4 If at any time it is necessary to have personnel working in the Clean Rooms during closed days (Saturday, Sunday, or Holidays), it is the responsibility of the Manufacturing Supervisor to establish maintenance coverage. The Manufacturing Supervisor must notify the designated Maintenance Supervisor no later than 11:00 A.M. of the last working day preceding the closed day in order to allow them to make arrangements to have Maintenance cleaning personnel available.
- 5.5 Repair similar to type and scope conducted in the assembly area may be performed, provided the operations are performed by qualified personnel and under the direction of the Area Supervisor.
- 5.6 The Clean Room Area Supervisor must be notified prior to repair of equipment or units. The Supervisor will then determine the necessary cleaning, if any, to be performed.



## 6. Maintenance

- 6.1 Cabinets and all surfaces are cleaned at least once during each eight (8) hour shift with a clean lint-free cloth, M-41572 AP, or a vacuum cleaner. Cabinets are washed once a week with a liquid detergent and water.
- 6.2 Equipment is wiped with a lint-free cloth, M 41572 AP or according to manufacturer's recommendation at least once daily.
- 6.3 Floors in the Clean Room area, air locks, reception room, and cleaning rooms are mopped with liquid detergent and water weekly, and vacuumed weekly at a time when the occupancy of the room is at a minimum.
- 6.4 Windows are cleaned weekly using a spray liquid cleaner and lint free wiping material.
- 6.5 Walls are vacuum-cleaned weekly and cleaned with a liquid detergent and water as required to maintain general cleanliness.
- 6.6 Gelatin mats are cleaned twice daily with kerosene. Sticky paper mats are replaced as required to maintain effectiveness.
- 6.7 Dust preventative clothing is cleaned twice a week.